WILLIAM HARVEY AND THE DISCOVERY OF THE CIRCULATION OF THE BLOOD

By Thomas H. Huxley

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I DESIRE this evening to give you some account of the life and labours of a very noble Englishman—William Harvey.

William Harvey was born in the year 1578, and as he lived until the year 1657, he very nearly attained the age of 80. He was the son of a small landowner in Kent, who was sufficiently wealthy to send this, his eldest son, to the University of Cambridge; while he embarked the others in mercantile pursuits, in which they all, as time passed on, attained riches.

William Harvey, after pursuing his education at Cambridge, and taking his degree there, thought it was advisable—and justly thought so, in the then state of University education—to proceed to Italy, which at that time was one of the great centres of intellectual activity in Europe, as all friends of freedom hope it will become again, sooner or later. In those days the University of Padua had a great renown; and Harvey went there and studied under a man who was then very famous—Fabricius of Aquapendente. On his return to England, Harvey became a member of the College of Physicians in London, and entered into practice; and, I suppose, as an indispensable step thereto, proceeded to marry. He very soon became one of the most eminent members of the profession in London; and, about the year 1616, he was elected by the College of Physicians their Professor of Anatomy. It was while Harvey held this office that he made public that great discovery of the circulation of the blood and the movements of the heart, the nature of which I shall endeavour by-and-by to explain to you at length. Shortly afterwards, Charles the First having succeeded to the throne in 1625, Harvey became one of the king's physicians; and it is much to the credit of the unfortunate monarch—who, whatever his faults may have been, was one of the few English monarchs who have shown a taste for art and science—that Harvey became his attached and devoted friend as well as servant; and that the king, on the other hand, did all he could to advance Harvey's investigations. But, as you know, evil times came on; and Harvey, after the fortunes of his royal master were broken, being then a man of somewhat advanced years—over 60 years of age, in fact—retired to the society of his brothers in and near London, and among them pursued his studies until the day of his death. Harvey's career is a life which offers no salient points of interest to the biographer. It was a life devoted to study and investigation; and it was a life the devotion of which was amply rewarded, as I shall have occasion to point out to you, by its results.

Harvey, by the diversity, the variety, and the thoroughness of his

investigations, was enabled to give an entirely new direction to at least two branches—and two of the most important branches—of what now-a-days we call Biological Science. On the one hand, he founded all our modern physiology by the discovery of the exact nature of the motions of the heart, and of the course in which the blood is propelled through the body; and, on the other, he laid the foundation of that study of development which has been so much advanced of late years, and which constitutes one of the great pillars of the doctrine of evolution. This doctrine, I need hardly tell you, is now tending to revolutionise our conceptions of the origin of living things, exactly in the same way as Harvey's discovery of the circulation in the seventeeth century revolutionised the conceptions which men had previously entertained with regard to physiological processes.

It would, I regret, be quite impossible for me to attempt, in the course of the time I can presume to hold you here, to unfold the history of more than one of these great investigations of Harvey. I call them "great investigations," as distinguished from "large publications." I have in my hand a little book, which those of you who are at a great distance may have some difficulty in seeing, and which I value very much. It is, I am afraid, sadly thumbed and scratched with annotations by a very humble successor and follower of Harvey. This little book is the edition of 1651 of the 'Exercitationes de Generatione'; and if you were to add another little book, printed in the same small type, and about one-seventh of the thickness, you would have the sum total of the printed matter which Harvey contributed to our literature. And yet in that sum total was contained, I may say, the materials of two revolutions in as many of the main branches of biological science. If Harvey's published labours can be condensed into so small a compass, you must recollect that it is not because he did not do a great deal more. We know very well that he did accumulate a very considerable number of observations on the most varied topics of medicine, surgery, and natural history. But, as I mentioned to you

just now, Harvey, for a time, took the royal side in the domestic quarrel of the Great Rebellion, as it is called; and the Parliament, not unnaturally resenting that action of his, sent soldiers to seize his papers. And while I imagine they found nothing treasonable among those papers, yet, in the process of rummaging through them, they destroyed all the materials which Harvey had spent a laborious life in accumulating; and hence it is that the man's work and labours are represented by so little in apparent bulk.

What I chiefly propose to do to-night is to lay before you an account of the nature of the discovery which Harvey made, and which is termed the Discovery of the Circulation of the Blood. And I desire also, with some particularity, to draw your attention to the methods by which that discovery was achieved; for, in both these respects, I think, there will be much matter for profitable reflection.

Let me point out to you, in the first place, with respect to this important matter of the movements of the heart and the course of the blood in the body, that there is a certain amount of knowledge which must have been obtained without men taking the trouble to seek it—knowledge which must have been taken in, in the course of time, by everybody who followed the trade of a butcher, and still more so by those people who, in ancient times, professed to divine the course of future events from the entrails of animals. It is quite obvious to all, from ordinary accidents, that the bodies of all the higher animals contain a hot red fluid—the blood. Everybody can see upon the surface of some part of the skin, underneath that skin, pulsating tubes, which we know as the arteries. Everybody can see under the surface of the skin more delicate and softer looking tubes, which do not pulsate, which are of a bluish colour, and are termed the veins. And every person who has seen a recently killed animal opened knows that these two kinds of tubes to which I have just referred, are connected with an apparatus which is placed in the chest, which apparatus, in recently killed

animals, is still pulsating. And you know that in yourselves you can feel the pulsation of this organ, the heart, between the fifth and sixth ribs. I take it that this much of anatomy and physiology has been known from the oldest times, not only as a matter of curiosity, but because one of the great objects of men, from their earliest recorded existence, has been to kill one another, and it was a matter of considerable importance to know which was the best place for hitting an enemy. I can refer you to very ancient records for most precise and clear information that one of the best places is to smite him between the fifth and sixth ribs. Now that is a very good piece of regional anatomy, for that is the place where the heart strikes in its pulsations, and the use of smiting there is that you go straight to the heart. Well, all that must have been known from time immemorial—at least for 4,000 or 5,000 years before the commencement of our era—because we know that for as great a period as that the Egyptians, at any rate, whatever may have been the case with other people, were in the enjoyment of a highly developed civilisation. But of what knowledge they may have possessed beyond this we know nothing; and in tracing back the springs of the origin of everything that we call "modern science" (which is not merely knowing, but knowing systematically, and with the intention and endeavour to find out the causal connection of things)—I say that when we trace back the different lines of all the modern sciences we come at length to one epoch and to one country—the epoch being about the fourth and fifth centuries before Christ, and the country being ancient Greece. It is there that we find the commencement and the root of every branch of physical science and of scientific method. If we go back to that time we have in the works attributed to Aristotle, who flourished between 300 and 400 years before Christ, a sort of encyclopaedia of the scientific knowledge of that day—and a very marvellous collection of, in many respects, accurate and precise knowledge it is. But, so far as regards this particular topic, Aristotle, it must be confessed, has not got very far beyond common knowledge. He knows a little about the structure of the heart. I do not think that his

knowledge is so inaccurate as many people fancy, but it does not amount to much. A very few years after his time, however, there was a Greek philosopher, Erasistratus, who lived about three hundred years before Christ, and who must have pursued anatomy with much care, for he made the important discovery that there are membranous flaps, which are now called "valves," at the origins of the great vessels; and that there are certain other valves in the interior of the heart itself.

Fig. 1.—The apparatus of the circulation, as at present known. The capillary vessels, which connect the arteries and veins, are omitted, on account of their small size. The shading of the "venous system" is given to all the vessels which contain venous blood; that of the "arterial system" to all the vessels which contain arterial blood.

I have here (Fig. 1) a purposely rough, but, so far as it goes, accurate, diagram of the structure of the heart and the course of the blood. The heart is supposed to be divided into two portions. It would be possible, by very careful dissection, to split the heart down the middle of a partition, or so-called 'septum', which exists in it, and to divide it into the two portions which you see here represented; in which case we should have a left heart and a right heart, quite distinct from one another. You will observe that there is a portion of each heart which is what is called the ventricle. Now the ancients applied the term 'heart' simply and solely to the ventricles. They did not count the rest of the heart—what we now speak of as the 'auricles'—as any part of the heart at all; but when they spoke of the heart they meant the left and the right ventricles; and they described those great vessels, which we now call the 'pulmonary veins' and the 'vena cava', as opening directly into the heart itself.

What Erasistratus made out was that, at the roots of the aorta and the pulmonary artery (Fig. 1) there were valves, which opened in the direction indicated by the arrows; and, on the other hand,

that at the junction of what he called the veins with the heart there were other valves, which also opened again in the direction indicated by the arrows. This was a very capital discovery, because it proved that if the heart was full of fluid, and if there were any means of causing that fluid in the ventricles to move, then the fluid could move only in one direction; for you will observe that, as soon as the fluid is compressed, the two valves between the ventricles and the veins will be shut, and the fluid will be obliged to move into the arteries; and, if it tries to get back from them into the heart, it is prevented from doing so by the valves at the origin of the arteries, which we now call the semilunar valves (half-moon shaped valves); so that it is impossible, if the fluid move at all, that it should move in any other way than from the great veins into the arteries. Now that was a very remarkable and striking discovery.

But it is not given to any man to be altogether right (that is a reflection which it is very desirable for every man who has had the good luck to be nearly right once, always to bear in mind); and Erasistratus, while he made this capital and important discovery, made a very capital and important error in another direction, although it was a very natural error. If, in any animal which is recently killed, you open one of those pulsating trunks which I referred to a short time ago, you will find, as a general rule, that it either contains no blood at all or next to none; but that, on the contrary, it is full of air. Very naturally, therefore, Erasistratus came to the conclusion that this was the normal and natural state of the arteries, and that they contained air. We are apt to think this a very gross blunder; but, to anybody who is acquainted with the facts of the case, it is, at first sight, an exceedingly natural conclusion. Not only so, but Erasistratus might have very justly imagined that he had seen his way to the meaning of the connection of the left side of the heart with the lungs; for we find that what we now call the pulmonary vein is connected with the lungs, and branches out in them (Fig. 1). Finding that the greater part of this system of vessels was filled with air after death, this

ancient thinker very shrewdly concluded that its real business was to receive air from the lungs, and to distribute that air all through the body, so as to get rid of the grosser humours and purify the blood. That was a very natural and very obvious suggestion, and a highly ingenious one, though it happened to be a great error. You will observe that the only way of correcting it was to experiment upon living animals, for there is no other way in which this point could be settled.

Fig.2,—The Course of the Blood according to Galen (A.D. 170).

And hence we are indebted, for the correction of the error of Erasistratus, to one of the greatest experimenters of ancient or modern times, Claudius Galenus, who lived in the second century after Christ. I say it was to this man more than any one else, because he knew that the only way of solving physiological problems was to examine into the facts in the living animal. And because Galen was a skilful anatomist, and a skilful experimenter, he was able to show in what particulars Erasistratus had erred, and to build up a system of thought upon this subject which was not improved upon for fully 1,300 years. I have endeavoured, in Fig. 2, to make clear to you exactly what it was he tried to establish. You will observe that this diagram is practically the same as that given in Fig. 1, only simplified. The same facts may be looked upon by different people from different points of view. Galen looked upon these facts from a very different point of view from that which we ourselves occupy; but, so far as the facts are concerned, they were the same for him as for us. Well then, the first thing that Galen did was to make out experimentally that, during life, the arteries are not full of air, but that they are full of blood. And he describes a great variety of experiments which he made upon living animals with the view of proving this point, which he did prove effectually and for all time; and that you will observe was the only way of settling the matter. Furthermore, he demonstrated that the cavities of the left side of the heart—what we now call the left auricle and

the left ventricle—are, like the arteries, full of blood during life, and that that blood was of the scarlet kind—arterialised, or as he called it "pneumatised," blood. It was known before, that the pulmonary artery, the right ventricle, and the veins, contain the darker kind of blood, which was thence called venous. Having proved that the whole of the left side of the heart, during life, is full of scarlet arterial blood, Galen's next point was to inquire into the mode of communication between the arteries and veins. It was known before his time that both arteries and veins branched out. Galen maintained, though he could not prove the fact, that the ultimate branches of the arteries and veins communicated together somehow or other, by what he called 'anastomoses', and that these 'anastomoses' existed not only in the body in general but also in the lungs. In the next place, Galen maintained that all the veins of the body arise from the liver; that they draw the blood thence and distribute it over the body. People laugh at that notion now-a-days; but if anybody will look at the facts he will see that it is a very probable supposition. There is a great vein (hepatic vein—Fig. 1) which rises out of the liver, and that vein goes straight into the 'vena cava' (Fig. 1) which passes to the heart, being there joined by the other veins of the body. The liver itself is fed by a very large vein (portal vein—Fig. 1), which comes from the alimentary canal. The way the ancients looked at this matter was, that the food, after being received into the alimentary canal, was then taken up by the branches of this great vein, which are called the 'vena portae', just as the roots of a plant suck up nourishment from the soil in which it lives; that then it was carried to the liver, there to be what was called "concocted," which was their phrase for its conversion into substances more fitted for nutrition than previously existed in it. They then supposed that the next thing to be done was to distribute this fluid through the body; and Galen like his predecessors, imagined that the "concocted" blood, having entered the great 'vena cava', was distributed by its ramifications all over the body. So that, in his view (Fig. 2), the course of the blood was from the intestine to the liver, and from the liver into the great 'vena cava',

including what we now call the right auricle of the heart, whence it was distributed by the branches of the veins. But the whole of the blood was not thus disposed of. Part of the blood, it was supposed, went through what we now call the pulmonary arteries (Fig. 1), and, branching out there, gave exit to certain "fuliginous" products, and at the same time took in from the air a something which Galen calls the 'pneuma'. He does not know anything about what we call oxygen; but it is astonishing how very easy it would be to turn his language into the equivalent of modern chemical theory. The old philosopher had so just a suspicion of the real state of affairs that you could make use of his language in many cases, if you substituted the word "oxygen," which we now-a-days use, for the word 'pneuma'. Then he imagined that the blood, further concocted or altered by contact with the 'pneuma', passed to a certain extent to the left side of the heart. So that Galen believed that there was such a thing as what is now called the pulmonary circulation. He believed, as much as we do, that the blood passed through the right side of the heart, through the artery which goes to the lungs, through the lungs themselves, and back by what we call the pulmonary veins to the left side of the heart. But he thought it was only a very small portion of the blood which passes to the right side of the heart in this way; the rest of the blood, he thought, passed through the partition which separates the two ventricles of the heart. He describes a number of small pits, which really exist there, as holes, and he supposed that the greater part of the blood passed through these holes from the right to the left ventricle (Fig 2).

It is of great importance you should clearly understand these teachings of Galen, because, as I said just now, they sum up all that anybody knew until the revival of learning; and they come to this—that the blood having passed from the stomach and intestines through the liver, and having entered the great veins, was by them distributed to every part of the body; that part of the blood, thus distributed, entered the arterial system by the 'anastomoses', as

Galen called them, in the lungs; that a very small portion of it entered the arteries by the 'anastomoses' in the body generally; but that the greater part of it passed through the septum of the heart, and so entered the left side and mingled with the pneumatised blood, which had been subjected to the air in the lungs, and was then distributed by the arteries, and eventually mixed with the currents of blood, coming the other way, through the veins.

Yet one other point about the views of Galen. He thought that both the contractions and dilatations of the heart—what we call the 'systole' or contraction of the heart, and the 'diastole' or dilatation—Galen thought that these were both active movements; that the heart actively dilated, so that it had a sort of sucking power upon the fluids which had access to it. And again, with respect to the movements of the pulse, which anybody can feel at the wrist and elsewhere, Galen was of opinion that the walls of the arteries partook of that which he supposed to be the nature of the walls of the heart, and that they had the power of alternately actively contracting and actively dilating, so that he is careful to say that the nature of the pulse is comparable, not to the movement of a bag, which we fill by blowing into it, and which we empty by drawing the air out of it, but to the action of a bellows, which is actively dilated and actively compressed.

Fig 3.—The course of the blood from the right to the left side of the heart (Realdus Columbus, 1559).

After Galen's time came the collapse of the Roman Empire, the extinction of physical knowledge, and the repression of every kind of scientific inquiry, by its powerful and consistent enemy, the Church; and that state of things lasted until the latter part of the Middle Ages saw the revival of learning. That revival of learning, so far as anatomy and physiology are concerned, is due to the renewed influence of the philosophers of ancient Greece, and indeed, of Galen. Arabic commentators had translated Galen, and portions of his works had got into the language of the learned in

the Middle Ages, in that way; but, by the study of the classical languages, the original text became accessible to the men who were then endeavouring to learn for themselves something about the facts of nature. It was a century or more before these men, finding themselves in the presence of a master—finding that all their lives were occupied in attempting to ascertain for themselves that which was familiar to him—I say it took the best part of a hundred years before they could fairly see that their business was not to follow him, but to follow his example—namely, to look into the facts of nature for themselves, and to carry on, in his spirit, the work he had begun. That was first done by Vesalius, one of the greatest anatomists who ever lived; but his work does not specially bear upon the question we are now concerned with. So far as regards the motions of the heart and the course of the blood, the first man in the Middle Ages, and indeed the only man who did anything which was of real importance, was one Realdus Columbus, who was professor at Padua in the year 1559, and published a great anatomical treatise. What Realdus Columbus did was this; once more resorting to the method of Galen, turning to the living animal, experimenting, he came upon new facts, and one of these new facts was that there was not merely a subordinate communication between the blood of the right side of the heart and that of the left side of the heart, through the lungs, but that there was a constant steady current of blood, setting through the pulmonary artery on the right side, through the lungs, and back by the pulmonary veins to the left side of the heart (Fig.3). Such was the capital discovery and demonstration of Realdus Columbus. He is the man who discovered what is loosely called the 'pulmonary circulation'; and it really is quite absurd, in the face of the fact, that twenty years afterwards we find Ambrose Pare, the great French surgeon, ascribing this discovery to him as a matter of common notoriety, to find that attempts are made to give the credit of it to other people. So far as I know, this discovery of the course of the blood through the lungs, which is called the pulmonary circulation, is the one step in real advance that was made between the time of

Galen and the time of Harvey. And I would beg you to note that the word "circulation" is improperly employed when it is applied to the course of the blood through the lungs. The blood from the right side of the heart, in getting to the left side of the heart, only performs a half-circle—it does not perform a whole circle—it does not return to the place from whence it started; and hence the discovery of the so-called "pulmonary circulation" has nothing whatever to do with that greater discovery which I shall point out to you by-and-by was made by Harvey, and which is alone really entitled to the name of the circulation of the blood.

If anybody wants to understand what Harvey's great desert really was, I would suggest to him that he devote himself to a course of reading, which I cannot promise shall be very entertaining, but which, in this respect at any rate, will be highly instructive—namely, the works of the anatomists of the latter part of the 16th century and the beginning of the 17th century. If anybody will take the trouble to do that which I have thought it my business to do, he will find that the doctrines respecting the action of the heart and the motion of the blood which were taught in every university in Europe, whether in Padua or in Paris, were essentially those put forward by Galen, 'plus' the discovery of the pulmonary course of the blood which had been made by Realdus Columbus. In every chair of anatomy and physiology (which studies were not then separated) in Europe, it was taught that the blood brought to the liver by the portal vein, and carried out of the liver to the 'vena cava' by the hepatic vein, is distributed from the right side of the heart, through the other veins, to all parts of the body; that the blood of the arteries takes a like course from the heart towards the periphery; and that it is there, by means of the 'anastomoses', more or less mixed up with the venous blood. It so happens, by a curious chance, that up to the year 1625 there was at Padua, which was Harvey's own university, a very distinguished professor, Spigelius, whose work is extant, and who teaches exactly what I am now telling you. It is perfectly true that, some time before, Harvey's

master, Fabricius, had not only re-discovered, but had drawn much attention to certain pouch-like structures, which are called the valves of the veins, found in the muscular parts of the body, all of which are directed towards the heart, and consequently impede the flow of the blood in the opposite direction. And you will find it stated by people who have not thought much about the matter, that it was this discovery of the valves of the veins which led Harvey to imagine the course of the circulation of the blood. Now it did not lead Harvey to imagine anything of the kind. He had heard all about it from his master, Fabricius, who made a great point of these valves in the veins, and he had heard the theories which Fabricius entertained upon the subject, whose impression as to the use of the valves was simply this—that they tended to take off any excess of pressure of the blood in passing from the heart to the extremities; for Fabricius believed, with the rest of the world, that the blood in the veins flowed from the heart towards the extremities. This, under the circumstances, was as good a theory as any other, because the action of the valves depends altogether upon the form and nature of the walls of the structures in which they are attached; and without accurate experiment, it was impossible to say whether the theory of Fabricius was right or wrong. But we not only have the evidence of the facts themselves that these could tell Harvey nothing about the circulation, but we have his own distinct declaration as to the considerations which led him to the true theory of the circulation of the blood, and amongst these the valves of the veins are not mentioned.

Fig. 4.—The circulation of the blood as demonstrated by Harvey (A.D. 1628).

Now then we may come to Harvey himself. When you read Harvey's treatise, which is one of the most remarkable scientific monographs with which I am acquainted—it occupies between 50 and 60 pages of a small quarto in Latin, and is as terse and concise as it possibly can be—when you come to look at Harvey's work,

you will find that he had long struggled with the difficulties of the accepted doctrine of the circulation. He had received from Fabricius, and from all the great authorities of the day, the current view of the circulation of the blood. But he was a man with that rarest of all qualities—intellectual honesty; and by dint of cultivating that great faculty, which is more moral than intellectual, it had become impossible for him to say he believed anything which he did not clearly believe. This is a most uncomfortable peculiarity—for it gets you into all sorts of difficulties with all sorts of people—but, for scientific purposes, it is absolutely invaluable. Harvey possessed this peculiarity in the highest degree, and so it was impossible for him to accept what all the authorities told him, and he looked into the matter for himself. But he was not hasty. He worked at his new views, and he lectured about them at the College of Physicians for nine years; he did not print them until he was a man of fifty years of age; and when he did print them he accompanied them with a demonstration which has never been shaken, and which will stand till the end of time. What Harvey proved, in short, was this (see Fig. 4)—that everybody had made a mistake, for want of sufficiently accurate experimentation as to the actual existence of the fact which everybody assumed. To anybody who looks at the blood-vessels with an unprejudiced eye it seems so natural that the blood should all come out of the liver, and be distributed by the veins to the different parts of the body, that nothing can seem simpler or more plain; and consequently no one could make up his mind to dispute this apparently obvious assumption. But Harvey did dispute it; and when he came to investigate the matter he discovered that it was a profound mistake, and that, all this time, the blood had been moving in just the opposite direction, namely, from the small ramifications of the veins towards the right side of the heart. Harvey further found that, in the arteries, the blood, as had previously been known, was travelling from the greater trunks towards the ramifications. Moreover, referring to the ideas of Columbus and of Galen (for he was a great student of literature, and did justice to all his

predecessors), Harvey accepts and strengthens their view of the course of the blood through the lungs, and he shows how it fitted into his general scheme. If you will follow the course of the arrows in Fig. 4 you will see at once that—in accordance with the views of Columbus—the blood passes from the right side of the heart, through the lungs, to the left side. Then, adds Harvey, with abundant proof, it passes through the arteries to all parts of the body; and then, at the extremities of their branches in the different parts of the body, it passes (in what way he could not tell, for his means of investigation did not allow him to say) into the roots of the vents—then from the roots of the veins it goes into the trunk and veins—then to the right side of the heart—and then to the lungs, and so on.

That, you will observe, makes a complete circuit; and it was precisely here that the originality of Harvey lay. There never yet has been produced, and I do not believe there can be produced, a tittle of evidence to show that, before his time, any one had the slightest suspicion that a single drop of blood, starting in the left ventricle of the heart, passes through the whole arterial system, comes back through the venous system, goes through the lungs, and comes back to the place whence it started. But that is the circulation of the blood, and it was exactly this which Harvey was the first man to suspect, to discover, and to demonstrate.

But this was by no means the only thing Harvey did. He was the first who discovered and who demonstrated the true mechanism of the heart's action. No one, before his time, conceived that the movement of the blood was entirely due to the mechanical action of the heart as a pump. There were all sorts of speculations about the matter, but nobody had formed this conception, and nobody understood that the so-called systole of the heart is a state of active contraction, and the so-called diastole is a mere passive dilatation. Even within our own age that matter had been discussed. Harvey is as clear as possible about it. He says the movement of the blood is

entirely due to the contractions of the walls of the heart—that it is the propelling apparatus—and all recent investigation tends to show that he was perfectly right. And from this followed the true theory of the pulse. Galen said, as I pointed out just now, that the arteries dilate as bellows, which have an active power of dilatation and contraction, and not as bags which are blown out and collapse. Harvey said it was exactly the contrary—the arteries dilate as bags simply because the stroke of the heart propels the blood into them; and, when they relax again, they relax as bags which are no longer stretched, simply because the force of the blow of the heart is spent. Harvey has been demonstrated to be absolutely right in this statement of his; and yet, so slow is the progress of truth, that, within my time, the question of the active dilatation of the arteries has been discussed.

Thus Harvey's contributions to physiology may be summed up as follows: In the first place, he was the first person who ever imagined, and still more who demonstrated, the true course of the circulation of the blood in the body; in the second place, he was the first person who ever understood the mechanism of the heart, and comprehended that its contraction was the cause of the motion of the blood; and thirdly, he was the first person who took a just view of the nature of the pulse. These are the three great contributions which he made to the science of physiology; and I shall not err in saying—I speak in the presence of distinguished physiologists, but I am perfectly certain that they will endorse what I say—that upon that foundation the whole of our knowledge of the human body, with the exception of the motor apparatus and the sense organs, has been gradually built up, and that upon that foundation the whole rests. And not only does scientific physiology rest upon it, but everything like scientific medicine also rests upon it. As you know—I hope it is now a matter of popular knowledge—it is the foundation of all rational speculation about morbid processes; it is the only key to the rational interpretation of that commonest of all indications of disease, the state of the pulse; so that, both